# Multiaxial creep-fatigue deformation modeling and damage evaluation considering non-proportional loading effect

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In recent years, carbon neutral is one of the most significant measures for improving environment of the earth. To achieve the objective, using clear energy such as nuclear power generation to replace traditional power such as coal-fired power generation is essential. It is well known that components of nuclear power generation are subjected to complex loading conditions at elevated temperature, thermal stress induced by temperature vibration and mechanical loading may cause non-proportional loading in which the directions of principal stress or strain rotate in one cycle, non-proportional loading can reduce fatigue life of materials, significantly. Numerous of articles have been published on the abovementioned issue[1]. However, during service period, creep damage also exists which leads to components are borne to non-proportional creep-fatigue loading condition. Fatigue life prediction method under aforementioned condition is an open issue. Thus, to ensure safe operation of nuclear power generation, the relative research on investigating fatigue life prediction method and damage mechanism of materials under non-proportional creep-fatigue loading is significant.

In the current study, to propose fatigue life prediction method, non-proportional creep-fatigue tests using SUS 304 were performed. Moreover, to clarify the damage mechanism, SEM, EBSD and TEM observation were also carried out.

The multiaxial constitutive modeling combining the proposed unified viscoplasiticty model and an energy-based damage parameter[2] was established for life prediction. Fig. 1 shows the comparison between experimental and predicted results using the proposed constitutive modeling. All plots distribute within 1.5 factor band-line. Thus, it could be concluded that the established method could evaluate fatigue life under non-proportional loading condition for SUS 304 with high accuracy. Moreover, dislocation configurations are displayed in Fig. 2. The domination of slip type is switched from single slip to multi-slip under axial and axial creep-fatigue loading. Under non-proportional loading conditions, deformation mechanism is changed to wavy slip, as manifested by cell structure, which is the main reason for additional hardening.

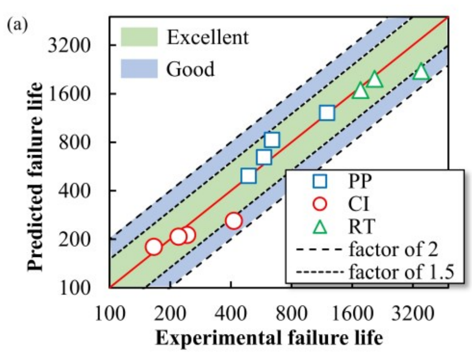


Fig. 1 Comparison between experimental and predicted results

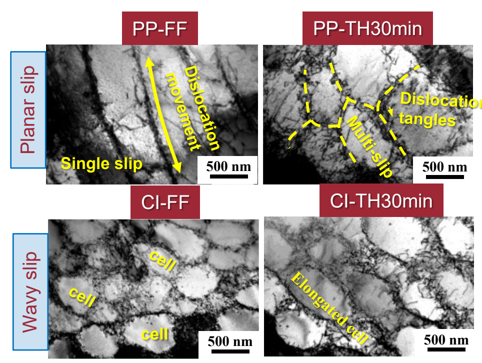


Fig. 2 Dislocation configuration under various loading condition

1) T. Itoh, M. Sakane, M. Ohnami, D.F. Socie, *J Eng Mater-T Asme*. **1995**, 285.
2) R.-Z. Wang, X.-C. Zhang, S.-T. Tu, S.-P. Zhu, C.-C. Zhang, *Int J Fatigue.* **2016**, *90*, 12.